SIDS INITIAL ASSESSMENT PROFILE

Chemical Category	C_7-C_9 Aliphatic Hydrocarbon Solvents Category
Chemical Names and CAS Registry Numbers	**Substance Name** — **CAS Number** *n-Paraffins Subcategory* n-Heptane — 142-82-5 n-Octane — 111-65-9 n-Nonane — 111-84-2 *Iso-Paraffins Subcategory* Pentane, 2,2,4-trimethyl- — 540-84-1 Alkanes, C_{7-8}, iso- — 70024-92-9 Alkanes, C_{7-10}, iso- — 90622-56-3 *Multi-Constituent Subcategory* Ligroine; petroleum ether — 8032-32-4 Naphtha, (petroleum), light catalytic reformed — 64741-63-5 Naphtha, (petroleum), solvent-refined light — 64741-84-0 Naphtha, (petroleum), hydrotreated heavy — 64742-48-9 Naphtha, (petroleum), hydrotreated light — 64742-49-0 Solvent naphtha, (petroleum), light aliphatic — 64742-89-8 Naphtha (petroleum), hydrodesulfurized light, dearomatized — 92045-53-9
Structural Formula and CAS Registry Numbers	**Structural Formula** — **CAS Number** *n-Paraffins Subcategory* CH_3-CH_2-CH_2-CH_2-CH_2-CH_2-CH_3 — 142-82-5 CH_3-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_3 — 111-65-9 CH_3-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_3 — 111-84-2 *Iso-Paraffins Subcategory*  — 540-84-1 UVCB substances containing aliphatic (linear and branched paraffins) molecules of carbon and hydrogen, predominantly in the C_7 to C_9 range — 70024-92-9, 90622-56-3 *Multi-constituent Subcategory* UVCB substances containing aliphatic (linear, branched, and cyclic paraffins) molecules of carbon and hydrogen, predominantly in the C_7 to C_9 range. The category only includes substances that have boiling ranges falling within approximately 90 to 151 degrees Celsius.* — 8032-32-4, 64741-63-5, 64741-84-0, 64742-48-9, 64742-49-0, 64742-89-8, 92045-53-9 * It should be noted that other substances defined by the same CAS RNs may have boiling ranges outside the range of 90-151degrees Celsius and that these substances are not covered by the category.

SUMMARY CONCLUSIONS OF THE SIAR

Category Definition/Justification

The C_7-C_9 Aliphatic Hydrocarbon Solvents Category is comprised of 13 CAS registry numbers (CAS RNs) that are associated with pure and multi-constituent aliphatic hydrocarbon solvent commercial chemicals, which typically contain <1% aromatics with a few members containing up to approximately 3% aromatics and n-hexane content typically <0.1%, with a few members containing up to approximately 5%. The multi-constituent chemicals are further defined by boiling range [90 to 151 degrees Celsius] and predominant carbon number range, which is primarily from C_7 to C_9. This category contains 4 single chemicals and 9 multi-constituent substances that include straight chain (n-), branched (iso-), and/or cyclic aliphatic hydrocarbons. In the European Union REACH (Registration, Evaluation, and Authorization of Chemicals) legislation, these multi-constituent category members are organized in a group described as "unknown or variable composition, complex reaction products or biological materials (UVCBs).

In this category, the 13 CAS RNs are commercial hydrocarbon solvents, whose composition and commercial applications provide the primary justification for evaluating these substances as a category. The majority of chemicals in this category are multi-constituent chemicals, some containing 30 to 50% cycloparaffins.

Based on structure and composition, the category has been divided into three subcategories. A general description of compositions of subcategory members with CAS RNs are as follows (see also table 1 and 2 in the appendix):

n-Paraffins Subcategory - 3 CAS RNs, each composed of a single, normal paraffin

- 142-82-5 Linear C_7 paraffin, n-heptane
- 111-65-9 Linear C_8 paraffin, n-octane
- 111-84-2 Linear C_9 paraffin, n-nonane

Iso-Paraffins Subcategory - 3 CAS RNs, one composed of a single isoparaffin and two composed of a range of isoparaffins predominantly in the C_7 to C_8 or C_7 to C_9 range, which includes 2,2,4-trimethylpentane that may also contain some normal paraffin content

- 540-84-1 Alkyl-branched C_8 isoparaffin, 2,2,4-trimethylpentane
- 70024-92-9 Alkanes, C_{7-8}, iso- [a multi-constituent substance that can be composed predominantly of alkyl-branched C_7 and C_8 isoparaffin isomers that can include 2,2,4-trimethylpentane as a constituent; other constituents can include methyl- hexanes and heptanes, dimethyl- pentanes and hexanes, and trimethylpentanes]
- 90622-56-3 Alkanes, $C_{7-10,}$ iso- [a multi-constituent substance that can be composed predominantly of branched C_7, C_8, and/or C_9 isoparaffin isomers, which can include methyl- hexanes, heptanes, and/or octanes; dimethyl- pentanes, hexanes, and/or heptanes; and trimethyl-pentanes and/or –hexanes]

Multi-constituent Subcategory - 7 CAS RNs composed of predominantly C_7 to C_9 paraffins with varying compositions of normal paraffins, isoparaffins, and/or cycloparaffins.

- 8032-32-4 Ligroine; petroleum ether (<1% aromatics, may contain up to 3% aromatics)
- 64741-63-5 Naphtha, (petroleum), light catalytic reformed
- 64741-84-0 Naphtha, (petroleum), solvent-refined light
- 64742-48-9 Naphtha, (petroleum), hydrotreated heavy
- 64742-49-0 Naphtha, (petroleum), hydrotreated light
- 64742-89-8 Solvent naphtha, (petroleum), light aliphatic
- 92045-53-9 Naphtha (petroleum), hydrodesulfurized light, dearomatized

For the environment, ECOSAR and read-across approaches have been used to address and support the data gaps for the category members. The available toxicology data show that the C_7-C_9 Aliphatic Hydrocarbon Solvents have similar levels of toxic potency under a variety of experimental conditions.

The category has been defined for members with specific purity/impurity profiles or composition as outlined in the full SIDS Initial Assessment Report and the SIDS Dossiers.

The conclusions of this assessment do not necessarily apply to substances with the same CAS number but different purity/impurity profiles or compositions.

Analog Identification

Analog chemicals (used to support the category members) contain hydrocarbon constituents that fall within the carbon number range of category members and consequently their data can be considered when assessing the potential toxicity of category members. The analog multi-constituent substances that contain up to 12% aromatics compared to multi-constituent category members that have a typical aromatic content of <1% with a few members containing up to approximately 3%; represent a worst-case example. Where data for streams with higher aromatic content are used to characterize mammalian toxicity endpoints, those substances are considered as conservative analogs (read-across candidates), which would be expected to exhibit greater toxicity than category members. n-Hexane was not used as a worst-case material because of its low content in multi-constituent C_7-C_9 hydrocarbon solvents (=< 5 percent; typical less than 0.1%). The use of multi-constituent analogs with much broader hydrocarbon number ranges and higher aromatic content is limited to the human health endpoints only [acute toxicity, repeated dose toxicity, reproductive/developmental toxicity]. Although the carbon number range for some of the analogs exceeds the category definition of C_7-C_9 hydrocarbon solvents, the use of those data to support the characterization of category members is a valid application of read-across techniques because the constituents outside the category carbon number are similar in that they are homologous with category member constituents, some of which may act by the same mode of toxic action, and exhibit toxicities that are comparable to category members. For example, for the developmental/reproductive endpoint, the light alkylate naphtha analog (CAS RN 64741-66-8) vapor contains ~40% C_7-C_9 isoparaffins with the balance of paraffins in the C5 range. The analog composition overlaps that of category member CAS RN 64742-89-8. The absence of adverse reproductive/developmental effects at a vapor concentration of 8000 ppm (24.7 mg/L) in which the C_7-C_9 isoparaffin content is fairly high, suggests that C_7-C_9 aliphatic hydrocarbons are unlikely to produce reproductive/developmental toxicity.

As identified by the US EPA TSCA Inventory, multi-constituent analog chemicals CAS RN 8032-32-4 (ligroine) and CAS RN 64741-63-5 (light catalytic reformed naphtha) have the same CAS RN designations as multi-constituent subcategory members but a broader hydrocarbon range and approximately 12% aromatics. This is because assignment of CAS RNs for hydrocarbon substances in the TSCA Inventory is generally based on a hierarchy of considerations including hydrocarbon type(s), carbon number and/or range, distillation temperature and/or range, and last processing step. These criteria may allow the same CAS RNs to be applied to different hydrocarbons and petroleum-derived substances (hydrocarbon streams). This may include somewhat different compositions and applications (e.g., solvents, fuels, lubricants, etc.). Similarly, different CAS RNs can be applied to substances of similar composition and application.

Data from CAS RN 108-87-2, methyl cyclohexane, is included to demonstrate the similarity in mammalian toxicity of those cycloparaffins, contained in multi-constituent paraffins. Other multi-constituent analogs with known composition information are used to support the aquatic toxicity endpoints because of their similar mode of toxic action, non-polar narcosis.

Data for the following analogs are also presented to support the characterization of selected endpoints.

Analog (CAS RN)	**Composition**	**Endpoint(s) Characterized**	**Data Location (Dossier CAS RN)**
108-08-7	2,4-Dimethylpentane (99+%)	Water solubility	90622-56-3
108-87-2	Methyl cyclohexane (toluene ~3%)	Acute toxicity (inhalation) Repeat dose toxicity (inhalation)	8032-32-4
108-87-2	C7-C8, cycloalkanes (methyl cyclohexane ~99%; C8 cycloparaffins ~1%)	Acute fish toxicity	64741-49-0
565-75-3	2,3,4-Trimethylpentane (99+%)	Acute invertebrate toxicity	90622-56-3
589-81-1	3-Methylheptane (99+%)	Water solubility	90622-56-3
591-76-4	2-Methyl hexane (99+%)	Water solubility	90622-56-3
2216-34-4	4-Methyloctane (99+%)	Water solubility	90622-56-3
3522-94-9	2,2,5-Trimethylhexane (99+%)	Water solubility	90622-56-3
8032-32-4	Ligroine, C_7-C_9 (n-/isoalkanes ~55% , cycloalkanes ~32%, and aromatics ~12%, which included 0.1% benzene)	Acute toxicity (inhalation) Repeat dose toxicity (inhalation)	8032-32-4
64741-63-5	Light catalytic reformed naphtha (paraffins ~86% and aromatics ~12%, which included 6%	Reproductive and developmental toxicity (inhalation)	64741-63-5

	benzene and 6% toluene)		
64741-66-8	Light alkylate naphtha (primarily C5-C9 iso-paraffins ~97%)	Repeat dose toxicity (inhalation) Reproductive and developmental toxicity (inhalation)	64742-89-8
64742-48-9	C9-C10, n-, iso-, cycloalkanes, <2% aromatics (paraffins ~99%)	Biodegradation	64742-48-9
64742-49-0	C9-C10, n-, iso-, cycloalkanes, <2% aromatics (paraffins ~98%)	Acute fish and invertebrate toxicity Alga toxicity Biodegradation	64742-49-0

Physicochemical Properties

The members of the C_7-C_9 Aliphatic Hydrocarbon Solvents Category are liquids at room temperature. The melting point values range from -127 to -51°C. The boiling points range from approximately 90 to 151°C. The vapour pressure values range from 5.9 to 61.3 hPa at 25°C. Water solubility values range from 0.12 to 28.4 mg/L with a relative density range of 0.68 to 0.76 g/cm^3. The log K_{ow} values for the category members range from 3.6 to 5.7.

Human Health

Toxicokinetics, Metabolism, and Distribution

C_7-C_9 Alkanes are readily absorbed and distributed through the body. Normal alkanes are readily metabolized and excreted in urine and expired as CO_2. Iso-alkanes are less readily metabolized to a range of metabolites that are excreted in the urine. Tissue/blood ratios are greater than unity (for C9 a brain/blood ratio of 11 and fat/blood ratios above 100 have been detected in rats), but biological concentrations decreased slightly with prolonged administration. For n-alkanes, there appears to be a very low rate of metabolism to potentially neurotoxic gamma diketones, and no such metabolism for the isoalkanes.

Metabolic profiles for C_7-C_9 alkanes correlate with toxicity results from animal studies. Low concentrations of n-nonane in the blood and high accumulation potential in the brain were seen within 1 day following inhalation exposure. In a study with n-heptane, the presence of low concentrations of the neurotoxic metabolite 2,5-heptanedione from inhalation treatment with n-heptane did not appear sufficient to produce clinical evidence of neurotoxicity. Metabolic studies with n-octane or n-nonane administered orally did not show any evidence of neurotoxic gamma diketones; results that correlate with the absence of clinical signs of neurotoxicity in repeated dose animal studies.

Comparison of excretion profiles following inhalation of the nephrotoxic isoalkane, 2,2,4-trimethylpentane (isooctane) with the non-nephrotoxic n-alkane, n-octane demonstrated that isooctane was absorbed and excreted more slowly than n-octane. These results suggested that greater exposure in the kidney to potentially toxic higher molecular weight metabolites of isooctane than to those of n-octane could be a factor in differences in nephrotoxicity between these materials.

These examples of similarities in metabolic profiles and animal toxicity for C_7-C_9 alkanes support the grouping of these substances as a category.

Acute Toxicity

The available acute toxicity data demonstrate that hydrocarbon solvent substances tested in the C_7-C_9 Aliphatic Hydrocarbon Solvents Category show a low order of toxicity by the oral, dermal, and inhalation routes of exposure. Clinical signs indicative of transient CNS depression were observed primarily with inhalation exposure at relatively high concentrations. Effects resolved within 2 days post-exposure. There was no apparent difference in inhalation toxicity (LC_{50} values) based on chemical structure as normal, branched, cyclic or multi-constituent product.

Acute Inhalation Toxicity

Multi-constituent Paraffins Subcategory

LC_{50} for category member C_7-C_9 (CAS RN 64742-49-0; < 0.1% aromatics) ranged from greater than 23 mg/L or greater than 33 mg/L to less than 42 mg/L in 2 separate studies. The LC_{50} of the analog chemical ligroine (CAS RN 8032-32-4; approx. 12% aromatics) was 16 mg/L. Since the analog chemical ligroine is considered a worst-case material in this sub-category due to 12% aromatic content, the LC_{50} value of 16 mg/L can used for read-across purposes, a value which falls in the conservative end of the inhalation acute toxicity range.

The LC_{50} for a cycloparaffin analog, methylcyclohexane (CAS RN 108-87-2) was greater than 40-50 mg/L demonstrating that cycloparaffins are unlikely to contribute significantly to acute toxicity in these complex substances.

Isoparaffins Subcategory

LC_{50} values were greater than 14 mg/L for 2,2,4 trimethyl pentane (CAS RN 540-84-1) and greater than 21 mg/L for a C_7-C_9 isoalkane (CAS RN 90622-56-3).

n-Paraffins Subcategory

LC_{50} ranged from 17 and 23.4 mg/L for n-nonane (CAS RN 111-84-2) to greater than 29.3 mg/L for n-heptane (CAS RN 142-82-5).

Acute Dermal Toxicity

The dermal LD_{50} in rabbits was greater than 2920 mg/kg bw (multi-constituent subcategory, CAS RN 64742-49-0) and greater than 3160 mg/kg bw for iso-paraffins category (C_7-C_9 isoalkanes, CAS RN 90622-56-3 and 2,2,4-trimethylpentane, CAS RN 540-84-1). No data were available for n-paraffins.

Acute Oral Toxicity (gavage administration)

The oral LD_{50} values in rats was greater than 15 g/kg bw for the n-paraffin, n-heptane (CAS RN 142-82-5). Two isoparaffin samples (2,2,4-trimethylpentane, CAS RN 540-84-1 and C_7-C_9 isoalkanes, CAS RN 90622-56-3) had LD_{50} values of greater than 5 g/kg bw and 10 ml/kg bw, respectively. In the multi-constituent subcategory, category member C_7-C_9 (CAS RN 64742-49-0; < 0.1% aromatics) had an oral LD_{50} in rats of greater than 5.8 g/kg bw and the analog methylcyclohexane (CAS RN 108-87-2) had an LD_{50} between 4-4.5 g/kg bw in rabbits. For each subcategory, the oral LD_{50} in rats exceeded 5 g/Kg. Since aliphatic hydrocarbons are low viscosity materials, the possibility of an aspiration hazard if orally ingested by humans should be considered.

Irritation

Members of the C_7-C_9 Aliphatic Hydrocarbon Solvents Category (tested for multi-constituent CAS RN 64742-49-0) are moderate skin irritants and cause irritation of the respiratory tract at high concentrations. No eye irritation was observed in rabbits. The category members do not have a potential to cause skin sensitization.

Repeated Dose Toxicity (Inhalation)

Five repeated dose inhalation studies conducted on C_7-C_9 aliphatic hydrocarbon substances and three analogs in the multi-constituent subcategory used to support the category consistently showed a low order of systemic toxicity. The no observed adverse effect level was often the highest concentration tested. The only generally significant effect observed in the animal inhalation studies was transient CNS depression. Male rat kidney effects consistent with alpha 2µ globulin nephropathy were observed in the isoparaffins, CAS RN 90622-56-3, 2,2,4 - trimethyl pentane (CAS RN 540-84-1), and the multi-constituent analog, light alkylate naphtha (CAS RN 64741-66-8) based on differential staining of kidney tissue. This nephropathy can be induced by exposure to long chain isoalkanes interacting with alpha 2µ globulin in the kidney, with a positive-structure activity response related to the degree of alkane branching. The content and distribution of iso-paraffins in multi-constituent substances would likely determine the expression of alpha 2µ globulin-related nephropathy. This nephropathy in male rats has been determined not to be relevant to human risk assessment. On the issue of neurotoxicity, several metabolism studies have demonstrated that the potentially neurotoxic 2,5-heptanedione is the n-heptane metabolite present in lowest concentrations in urine of rats and humans. However, none of the repeated dose studies, including a 28 week and a 16 week inhalation study with n-heptane, produced any overt signs of neurotoxicity.

Multi-constituent Paraffins Subcategory

A 13-week study employing a distillate vapour of an analog light alkylate naphtha (CAS RN 64741-66-8) compositionally similar to category member CAS RN 64742-89-8 resulted in an NOAEC of 6646 ppm, the highest dose tested (similar to OECD TG 413 with neurotoxicity endpoints). The NOAEC for the analog chemical ligroine (CAS RN 8032-32-4; approx 12% aromatics) was 1200 ppm, the highest dose tested in a 13-week study with rats or dogs (similar to OECD TG 413). Since ligroine is considered a worst-case material in this sub-category due to 12% aromatic content, the NOAEC value of 1200 ppm can be used for read-across purposes. Similar results were seen for the cycloparaffin analog, methylcyclohexane (CAS RN 108-87-2) in rabbits with an NOAEC of 1162 ppm administered for 10 weeks. Higher doses administered for differing durations to the rabbits produced body weight loss, respiratory effects, light narcosis, and convulsions prior to death. At non-lethal but high concentrations varying degrees of inflammatory responses and vascular lesions in various organs were seen with histopathology.

Iso-paraffins Subcategory

NOAEC for a C_7-C_9 isoalkane (CAS RN 90622-56-3) in a 13-week study in rats was 1180 ppm, the highest dose tested. There was no treatment related mortality and clinical/systemic findings were unremarkable with the exception of male rat nephropathy, which is not considered relevant to human.

Supplemental information: Numerous studies have been performed by the oral route and one subchronic study by inhalation (Short et al, 1989a) to explore the nephrotoxic activity of 2,2,4-trimethyl pentane (CAS RN 540-84-1) and alpha 2µ globulin (IRIS, 2007). Since these studies are often single dose levels and are not conducted according to guidelines and do not provide NOAEC values they are cited here to confirm the alpha 2µ globulin mediated nephrotoxicity induced by 2,2,4-trimethyl pentane.

n-Paraffins Subcategory

NOAEC values of one 28-week and one 16 week study in rats via inhalation with n-heptane (CAS RN 142-82-5) demonstrated no adverse effects at a dose of 1500 [only dose level tested – 16 weeks] or a maximum dose of 2970 ppm [highest dose tested, similar to OECD TG 413] respectively. In the 28-week study (NOAEC = 2970 ppm) labored or rapid breathing, slight prostration were observed during the first week. Other in-chamber clinical signs abated by the end of the second week of study. The NOAEC in a 13-week study for n-nonane (CAS RN 111-84-2) [protocol similar to OECD TG413] was 590 ppm [mid-dose] with a LOAEC of 1600 ppm [highest dose] based on decreased body weight gain and clinical signs, which included salivation and lacrimation, and mild loss of coordination and fine tremors during the first 4 days. Although a decrease in NOAEC was seen as the carbon number increased from 7 (n-heptane) to 9 (n-nonane), these data do not appear to reflect a major difference based on chemical structure.

Mutagenicity

All genetic toxicity studies were performed with category members, no analogs were employed. In vitro genotoxicity testing of C_7-C_9 aliphatic hydrocarbon solvent substances conducted in both bacterial and mammalian cells, including human cells, showed no indication of genotoxic activity. The dominant lethal study on the isoparaffinic hydrocarbon, CAS RN 90622-56-3 in this category showed no evidence of in vivo germ cell genotoxicity. A multi-constituent sub-category member, CAS RN 64742-49-0 did not induce cytogenetic damage in a mouse micronucleus assay (OECD TG 474), and genetic damage and repair (UDS) was not observed in laboratory animals treated with the isoparaffin 2,2,4-trimethylpentane (CAS RN 540-84-1). Results of these studies indicate that members of the C_7-C_9 Aliphatic Hydrocarbon Solvents Category do not cause genotoxicity in laboratory animals.

Reproductive and Developmental Toxicity

A weight-of-evidence approach using available data from the inhalation developmental toxicity study on a C_8 isoparaffinic substance (CAS RN 90622-56-3) and inhalation reproductive/developmental toxicity screening tests on two multi-constituent analog test substances (CAS RN 64741-63-5 and CAS RN 64741-66-8) combined with absence of adverse effects on reproductive organs from repeated exposure studies show no evidence that exposure to substances in the C_7-C_9 Aliphatic Hydrocarbon Solvents Category results in reproductive or developmental toxicity.

Reproductive Toxicity

Multi-constituent Paraffins Subcategory

Reproductive toxicity studies are available on two analogs.

Light catalytic reform naphtha vapour (CAS RN 64741-63-5), an analog containing approximately 4% n-hexane, 1% n-heptane, 11-12 % C_7-C_9 aliphatics and 12% aromatics (6% benzene and 6% toluene) was tested in a combined reproductive/developmental toxicity study according to modified OECD TG 421. The NOAEC for male parental effects was 2500 ppm (11.6 mg/L) based on increased relative liver to body weight ratio at 7500 ppm (34.9 mg/L). Parental male rats also showed increases in absolute and relative kidney weights consistent with alpha 2µ-globulin nephropathy but no differential staining was performed. The NOAEC for parental female (maternal toxicity) and developmental/reproductive effects was 7500 (34.9 mg/L), the highest dose tested.

The NOAEC for light alkylate naphtha vapour (CAS RN 64741-66-8, an analog containing ~40% C_7-C_9 isoparaffins) in the reproductive/developmental screening test was 8000 ppm (24.7 mg/L) the highest dose tested. The absence of reproductive toxicity at the high exposure concentration of 8000 ppm (24.7 mg/L) of light alkylate naphtha vapour comprised of ~40% C_7-C_9 isoparaffins indicates that C_7-C_9 aliphatic hydrocarbons do not adversely affect reproduction. Negative results from the light catalytic reformed naphtha (CAS RN 64741-63-5) vapour study also demonstrated a NOAEC value of 7500 ppm (34.9 mg/L) for reproductive endpoints. Although this chemical vapour contained approximately 12% C_7-C_9 aliphatics, the

absence of adverse reproductive effects supports the light alkylate naphtha results and further demonstrates that the presence of 4% n-hexane or 12% aromatics did not induce reproductive toxicity in this system.

No adverse effects were reported in reproductive organs (testes, epididymides, ovaries) in inhalation repeat dose studies for the multi-constituent subcategory analog chemicals light alkylate naphtha (CAS RN 64741-66-8), ligroine (CAS RN 8032-32-4, 12% aromatics) in rats or methylcyclohexane (CAS RN 108-87-2) in rabbits.

The absence of reproductive or developmental toxicity for these worst-case materials supports the position that chemicals in the C_7-C_9 Aliphatic Hydrocarbon Solvents Category do not cause any developmental or reproductive toxicity.

Isoparaffins Subcategory

No reproductive toxicity studies are available. No adverse effects were reported in reproductive organs (testes, epididymides, ovaries) examined in a 12- week inhalation repeat dose study with CAS RN 90622-56-3.

n-Paraffins Subcategory

No reproductive toxicity studies are available. No adverse effects were reported in reproductive organs (testes, epididymides, ovaries) examined in a 28-week inhalation repeat dose studies with n-heptane (CAS RN 142-82-5) or in a 13-week inhalation repeat dose study with n-nonane (CAS RN 111-84-2).

Developmental Toxicity

Multi-constituent Paraffins Subcategory

See reproductive toxicity endpoint above.

Isoparaffins Subcategory

A standard inhalation teratology study (Segment II) on C_7-C_9 isoalkane, CAS RN 90622-56-3, showed no evidence of embryonic or teratogenic in rats. The NOAEC was 1200 ppm, the highest dose tested.

n-Paraffins Subcategory

No data are available; read-across will be used from the multi-constituents subcategory.

The absence of embryonic or teratogenic toxicity in the standard developmental study (Segment II) with the isoparaffin CAS RN 90622-56-3 considered in conjunction with the absence of developmental toxicity in the reproductive/developmental studies with the multi-constituent analog substances CAS RN 64741-66-8 and CAS RN 64741-63-5 (modified OECD TG 421) indicate that members of the C_7-C_9 aliphatic hydrocarbons solvents category are unlikely to be developmental toxicants.

Carcinogenicity

No standard carcinogenicity studies are available with members of the category. Negative results were found in a non-guideline 2-year dermal carcinogenicity study in mice with light alkylate naphtha (LAN, CAS RN 64741-66-8 - analog). No category members contain benzene levels above 0.01%.

Neurotoxicity

No overt clinical signs of neurotoxicity were induced by C_7-C_9 aliphatic hydrocarbon solvent substances in animal repeated dose toxicity studies although transient CNS depression was observed in acute and repeated dose toxicity studies. Measurement of various parameters of neurobehavioral response in showed minimal to no adverse effects and in all cases values were comparable to controls after a recovery period. Studies in experimental animals do not produce peripheral neuropathies using n-heptane. However data from a tire worker study and a case-report suggested “minimal” peripheral neuropathy may be induced by exposure to high concentrations of solvents including n-heptane although the effects among tyre workers were subclinical and expressed by electrophysiological data and a separate case report involved exposure to mixed solvent glue. Another worker study at lower exposure levels showed no clinical signs of neurotoxicity. Overall the substances in this category do not produce neurotoxic metabolites similar to 2,5-heptanedione from n-heptane and are unlikely to present a hazard as neurotoxicants.

These chemicals may possess properties indicating hazard for human health (moderate skin irritation, irritation of the respiratory tract, and transient CNS effects at high exposure concentrations). Adequate screening-level data are available to characterize the human health hazard for the purposes of the OECD HPV Chemicals Programme.

Environment

Members of the C_7-C_9 Aliphatic Hydrocarbon Solvents Category are not expected to undergo hydrolysis in

the environment, due to the lack of hydrolyzable functional groups. All chemicals in this category have the potential to rapidly volatilize from surface waters, based on Henry's Law constants (HLC) representing volatility for category members that range from 29,559 to 302,171 Pa-m^3/mole. In the air, category members have the potential to degrade through indirect photolytic processes mediated primarily by hydroxyl radicals ($^{\bullet}OH$) with calculated degradation half-lives ranging from 4.8 to 27.7 hours or 0.4 to 2.3 days, based on a 12-hr day and a $^{\bullet}OH$ concentration of 1.5×10^6 $^{\bullet}OH/cm^3$.

Guideline and non-guideline studies are available to evaluate the biodegradability of category members. Members of the n-paraffins subcategory have the potential to biodegrade rapidly based on results that support their characterization as readily biodegradable (CAS RN 142-82-5, CAS RN 111-65-9, CAS RN 111-84-2). In comparison, members of the iso- subcategory are considered as not readily biodegradable based on results for one of the multi-constituent isoparaffinic substances, which was shown not to be readily biodegradable, 22.4% by day 28 using OECD TG 301F (CAS RN 90622-56-3). Multi-constituent subcategory members are expected to be readily biodegradable based on results from several studies that resulted in greater than 60% biodegradation after 28 days using OECD TG 301F, but not meeting the 10-day window criterion (CAS RN 92045-53-9, CAS RN 64742-49-0 analog, CAS RN 64742-48-9 analog). The result for each multi-constituent substance (UVCB) characterizes the biodegradability of that substance as a whole, but it does not suggest that each constituent of the UVCB is equally biodegradable. As with all ready biodegradation test guidelines, the test system and study design used with these substances (OECD TG 301F) is not capable of distinguishing the relative contribution of the substances' constituents to the total biodegradation measured (constituents with higher branching/cyclic structures may degrade to a lesser extent than linear and less branched structures).

Mackay Level III modeling indicates that category members partition primarily to the air and water compartments when an equal emission rate (1000 kg/hr) to the air, water, and soil compartment is assumed. When release occurs only to either the air or water compartment, members are indicated by the model to partition largely to the compartment to which they are released. When release occurs only to the soil compartment, members are indicated in the modeling to partition to the air and soil compartments. For three representative chemicals from this category, Level III percent partitioning results using an emission rate of 1000 kg/hr to each of the air, water, and soil compartments are as follows:

n-Octane (n-Paraffins Subcategory)
- Air 10.3
- Water 33.9
- Soil 11.7
- Sediment 44.1

2,2,4-Trimethyl Pentane (Iso-Paraffins Subcategory)
- Air 20.2
- Water 64.3
- Soil 1.9
- Sediment 13.6

1,2,4-Trimethyl Cyclohexane (Multi-constituent Subcategory)
- Air 12.7
- Water 46.1
- Soil 26.1
- Sediment 15.1

When released primarily to the air compartment, the primary mode of removal would be via photodegradation. Although the substances and their chemical constituents demonstrate a range of water solubility with some constituents having relatively low solubility, wet deposition of category chemical constituents is not likely to play a significant role in their atmospheric fate because of their rapid photodegradation. Volatilization to the air can contribute to the loss of category chemical constituents from aqueous and terrestrial habitats.

Category members are expected to sorb to organic matter in soil, sediment, and wastewater solids based on estimated log K_{oc} values ranging from 3.0 to 4.7. Category members have a potential to bioaccumulate, based on a measured BCF value of 199 in a mussel (*Mytilus edulis*) for n-octane that used a limited study design and calculated BCF values (BCFBAF v3.0 model from the EPI Suite Program) that range from 105 (n-nonane) to 1216 (n-octane) (log BCF = 2.02 to 3.08) for the single substances. These predictions capture the range of log K_{ow} within the category and do not consider biotransformation. These data suggest a low to moderate order of bioaccumulative potential for category members.

Aquatic Toxicity

Acute Toxicity

Sufficient data are available to characterize the fish and invertebrate acute toxicity and alga toxicity of the C_7-C_9 Aliphatic Hydrocarbon Solvents Category. Category members are expected to exhibit 48- to 96-hour effect concentrations for the three subcategories within a relatively narrow range based on measured and calculated results that range from 0.04 to 1.6 mg/L for the n-paraffins subcategory, 0.11 to 0.4 mg/L for the iso- subcategory, and 0.13 to 0.7 mg/L for the multi-constituent subcategory.

Multi-constituent Subcategory

There are measured aquatic toxicity data for five members of the multi-constituent subcategory and two analog substances. Measured 96-hr fish LC_{50} values range from 0.3 to 1.3 mg/L. Measured 48-hr daphnid EC_{50} values range from 0.7 to 0.9 mg/L. The algae effects data are from three studies, one of which reported measured values for a substance that is largely C_9 to C_{10}. The measured 72-hr EC_{50} value is 0.4 mg/L.

There are measured chronic aquatic toxicity data for one member of the multi-constituent subcategory that can be used to characterize the chronic toxicity of category members. The 21-day NOELR value was 1.0 mg/L and the NOEC value was 0.17 mg/L, based on reproduction. The 21-day LOELR value was 2.0 mg/L and the LOEC value was 0.32 mg/L, based on reproduction. The 21-day EL_{50} and EC_{50} values from this study were 1.6 and 0.23 mg/L, respectively. These data are representative of the category as a whole because the substance contains the range of carbon numbers and hydrocarbon types found in the three subcategories.

Iso-Paraffins Subcategory

There are calculated and measured aquatic toxicity data for the single analog chemical substance, 2,3,4-trimethylpentane (2,3,4-TMP) that are used as read-across data to 2,2,4-trimethylpentane (2,2,4-TMP), and measured acute aquatic toxicity data for hydrocarbons, C7-C9, isoalkanes (CAS RN 90622-56-3). Additionally, data from the multi-constituent subcategory can also be used as read-across data because these substances contain significant amounts of isoparaffins and have carbon number ranges that are similar to and overlap with the two multi-constituent members, CAS RN 70024-92-9 and CAS RN 90622-56-3. Calculated and measured 96-hr fish LC_{50} values for two subcategory members range from 0.11 to 1.28 mg/L. Measured 48-hr daphnid data, 0.2 mg/L, and 96-hr LC_{50} marine invertebrate data, 0.4 and 0.9 mg/L, are available for 2,3,4-TMP. These data are consistent with the data identified for the multi-constituent subcategory, which is expected given the reasons mentioned above. The alga data used to characterize the iso-paraffin subcategory are from the multi-constituent subcategory with a 72-hr EC_{50} value of 0.4 mg/L.

n-Paraffins Subcategory

The acute aquatic toxicity of the three members of the n-paraffins subcategory can be characterized using calculated and measured data for these substances, as well as read-across data from the iso- and multi-constituent subcategories. Calculated acute data for fish (96-hr) are 0.49, 0.14, and 0.06 mg/L, for n-heptane, n-octane, and n-nonane, respectively. Although there are no measured data for these three members, the use of the calculated data are supported by the measured values from the iso- and multi-constituent subcategories, which range from 0.11 to 1.3 mg/L, as well as the measured daphnid data. The daphnid 48-hr effect values are 1.5, 0.3, and 0.2 mg/L, for n-heptane, n-octane, and n-nonane, respectively. All other measured invertebrate results (96-hr values) that show effects are for two marine species and range between 0.1 to 0.2 mg/L for the three paraffins. Calculated toxicity data for green alga (72-hr) are 0.56, 0.24, and 0.14 mg/L, for n-heptane, n-octane, and n-nonane, respectively. Although there are no measured data for these three members, the use of the calculated data are supported by the measured values from the multi-constituent subcategory, which exhibited a low 72-hr EC_{50} value of 0.4 mg/L, as well as the measured acute fish and daphnid data that ranged from 0.06 to 1.5 mg/L.

Chronic Toxicity

There are measured chronic aquatic toxicity data for one member of the multi-constituent subcategory, containing C_7-C_9 n-alkanes, isoalkanes, and cyclics. The 21-day LOEC value was 0.32 mg/L and the NOEC value was 0.17 mg/L, based on reproduction. The 21-day EC_{50} value from this study was 0.23 mg/L, based on survival. Additional estimated daphnid chronic toxicity data for n-heptane, 2,2,4-trimethylpentane, and nonane range from 0.23 to 0.06 mg/L.

Chemicals in this category possess properties indicating a hazard for the environment (acute toxicity for fish, invertebrates, and algae; chronic toxicity for invertebrates values <1 mg/L). Category members have a low to moderate bioaccumulative potential. Multi-constituent and n-paraffin category members are readily biodegradable, while isoparaffinic members are not. Adequate screening-level data are available to characterize the environmental hazard for the purposes of the OECD HPV Chemicals Programme.

Production/Use/Exposure

Production

As reported to the U.S. Environmental Protection Agency for the year 2005, companies produced or imported the following volumes of C_7-C_9 hydrocarbon solvents:

- n-Heptane, CAS RN 142-82-5: 4500-22,500 metric tons (10 million to < 50 million pounds)
- n-Octane, CAS RN 111-65-9: 450-4500 metric tons (1 million to < 10 million pounds**)**
- n-Nonane, CAS RN 111-84-2: 225-<450 metric tons (500,000 to < 1 million pounds)
- Pentane, 2,2,4-trimethyl-, CAS RN 540-84-1: 45,000-225,000 metric tons (100 to <500 million pounds)
- Alkanes, C_{7-8}, iso-, CAS RN 70024-92-9: 450-4500 metric tons (1 million to < 10 million pounds**)**
- Alkanes, $C_{7-10,}$ iso-, CAS RN 90622-56-3: No data
- Ligroine; petroleum ether, CAS RN 8032-32-4: < 225 metric tons (< 500,000 pounds)
- Naphtha, (petroleum), light catalytic reformed, CAS RN 64741-63-5: 450,000 or greater metric tons (1 billion pounds or greater)
- Naphtha, (petroleum), solvent-refined light, CAS RN 64741-84-0: 450,000 or greater metric tons (1 billion pounds or greater)
- Naphtha, (petroleum), hydrotreated heavy, CAS RN 64742-48-9: 450,000 or greater metric tons (1 billion pounds or greater)
- Naphtha, (petroleum), hydrotreated light, CAS RN 64742-49-0: 450,000 or greater metric tons (1 billion pounds or greater)
- Solvent naphtha, (petroleum), light aliphatic, CAS RN 64742-89-8: 225,000 to < 450,000 metric tons (500 million to < 1 billion pounds)
- Naphtha (petroleum), hydrodesulfurized light, dearomatized, CAS RN 92045-53-9: No data

Use

Hydrocarbon solvents in the C_7-C_9 range have several applications including uses in paints, coatings, and adhesives. They are also used as degreasers and gasoline additive diluents, and in chemical reactions. However, because of their evaporative properties the predominant commercial use of many category members is in paints and coatings.

Common names for substances in the C_7-C_9 Aliphatic Hydrocarbon Solvents Category include, heptane, isooctane, Varnish Makers & Painters Naphtha (VM&P naphtha), and special boiling point (SBP) aliphatic solvent. Heptane is used to purify pharmaceuticals and isooctane is used to carry out synthetic organic chemical reactions in the pharmaceutical industry that are difficult or impossible in other solvents. Another use of category members is indicated by the generic name, Lacquer Diluent, which identifies an application where the purpose of the solvent is to dilute and reduce the cost after a resin has been dissolved in the primary active solvent. Lacquers are still commonly used for wood furniture coatings. VM&P naphtha is used primarily in industrial coatings and finishes. Other process applications include printing (press operation and ink mixing), adhesion, and fiberglass and polyurethane molding.

Exposure

The sources for potential environmental exposure to C_7-C_9 aliphatic hydrocarbon solvent substances could include releases from chemical and petroleum manufacturing/processing facilities, releases from facilities that use C_7-C_9 aliphatic hydrocarbon solvent substances, releases from consumer products that include C7 to C9 aliphatics, automotive sources (fuel evaporate emissions and exhaust), and possibly biogenic and combustion sources.

C_7-C_9 Aliphatic Hydrocarbon Solvents Category members are used in paints, coatings, and adhesives, and as chemical reaction media, degreasers, and gasoline additive diluents. However, the predominant commercial use of category members is in paints and coatings where their performance is based on their evaporative properties. Therefore, the primary route of exposure is expected to be inhalation from evaporative emissions resulting from these uses.

Occupational exposure includes workers exposed during the manufacture of the product stream and includes office workers. In general, occupational (manufacturing) exposure to category members is well within applicable exposure limits, and office air data are comparable to ambient residential levels.

A database was compiled of occupational air concentration data from approximately 100 journal articles, which were selected from an initial list of 22,000 papers, and the hydrocarbon solvent data published from those articles. The authors selected 35 “indicators”, defined as constituents of, or surrogates for category members. They included heptane, VM&P Naphtha (Hydrocarbons, C_7-C_9, n-alkanes, isoalkanes, cyclics), octane, and nonane; expressing concentrations as a fraction of the TLV (threshold limit value), the authors reported values for these 4 indicators as less than 3, 4, 1, and 1%, respectively. In general, hydrocarbon levels have decreased four-fold over the period 1960 to 1998 and the average level has been below 40% of the TLV

since 1980.

One company supplied industrial hygiene data for category members covering the period 1996 to 2003. The tasks associated with these data were either operations or distribution, which involved loading operations. The geometric mean for the category member concentration in air was below 1 (both ppm and mg/m^3) with a range of 0.001 to 12 ppm (0.004 to 56 mg/m^3).

Hodgson and Levin (2003) reported air concentrations of some of the C_7-C_9 category substances (n-heptane, n-octane, n-nonane, 2,2,5-trimethylhexane, and methylcyclohexane) in office buildings. They reported central tendency (geometric mean or median) and maximum concentration. Of the C_7 to C_9 category chemicals detected in office buildings, all concentrations were low (under 2 ug/m^3). Maximum values were reported as 2.9, 60, 29, 2.9, 3.1, and 1.6 ug/m^3 for n-heptane, n-octane, n-nonane, 3-methylhexane, methylcyclohexane, and 2,2,5-trimethylhexane, respectively. These levels are only slightly higher than those reported for residences.

Qualitative exposure data by occupational category is provided by the National Household Products Database. These data indicate that workers in a variety of industries are potentially exposed to products containing C_7 to C_9 category substances. These include those manufacturing or otherwise exposed to adhesives and sealants, paints and coatings, vinyl flooring, ceiling tiles, cabinetry, wall coverings, HVAC insulation, construction, maintenance, landscaping, pesticides, and auto products.

Non-occupational exposure includes ambient outdoor air exposure and indoor air exposure in the home. Such exposures could occur from using consumer products containing the solvent and from indirect sources including ambient air, drinking water, food, and natural sources. A potentially significant source of exposure unrelated to hydrocarbon solvents is from petroleum fuels and transportation.

APPENDIX (will be removed when SIAP and SIAR are merged)

Table 1. Predominant carbon number range and paraffin class percent composition of commercial solvents under CAS RNs in the iso-paraffins and multi-constituent subcategories of the C_7-C_9 Aliphatic Hydrocarbon Solvents Category

Subcategory and CAS Number	Carbon Number / Range	n-, Iso-Paraffins (%)	Cyclo-paraffins (%)
Iso-Paraffins			
70024-92-9	7-8	100	0
90622-56-3	7-9	100	0
Multi-constituent*			
8032-32-4	7-9	~40-42	~56-57
64741-63-5	7	~90	~10
64741-84-0	6-8	na	na
64742-48-9	7-10	~40-52	~44-52
64742-49-0	6-9	na	na
64742-89-8	7-10	~1-91	~9-99
92045-53-9	7	na	na

na not available

*** data only pertain to category members with boiling-point ranges within 90-151 degrees Celsius.**

Table 2. Representative characteristics of C_7-C_9 aliphatic hydrocarbon solvents

Property or Characteristic	Value Range or Constituents
Predominant carbon number range	7 to 9
Distillation range, °C (°F)	~90 to ~151 (194 to 304)
Aromatics (%)	<1, typical (a few members may contain up to approximately 3.0%)
n-Hexane (%)	<0.1, typical (a few members may contain up to approximately 5%)
Benzene (ppmv)	<100
Sulfur (ppmv)	<100
Typical n-paraffins*	n-Heptane n-Octane n-Nonane
Typical iso-paraffins*	2-Methylhexane 2,4-Dimethylpentane 3-Methylheptane 2,2,4-Trimethylpentane 2-Methyloctane 4-Methyloctane
Typical cyclo-paraffins* (naphthenics)	Methylcyclohexane Ethylcyclohexane 1,2,4-Trimethylcyclohexane 2,2,5-Trimethylcyclohexane

* typical constituents representing multi-constituent category members were selected on the basis of carbon number, chemistry/structure, measured distillation ranges, and hydrocarbon process (distillation) knowledge

Table X *(# to be determined once placed in SIAR).* A comparison between typical C_7-C_9 Aliphatic Hydrocarbon Solvents Category member parameters, study summary compositions, and production parameters listed for multi-constituent substances in technical specification sheets and MSDSs.

CAS RN	Name	Boiling Range ºC (ºF)	Aromatics* (% wt)	Benzene (% wt)	n-Hexane** (% wt)	Paraffins, n-, iso- (% wt)	Paraffins, cyclo- (% wt)	Composition Notes (% wt)
	C_7-C_9 Aliphatic Hydrocarbon Solvents Category	~90 to ~151 (~194 to ~304)	<1 (typical)	<0.01 (typical)	<0.1 (typical)	~1 to ~99	~1 to ~99	n-, iso-, and/or cyclo-paraffins that fall primarily within the C7 to C9 range
64742-49-0	Hydrocarbons, C6-C7, n-alkanes, isoalkanes, cyclics, <5% n-hexane (European)	87 to 101 (189 to 214)	<0.0005	0.0003	3	~65	~35	na
	Hydrocarbons, C7, n-alkanes, isoalkanes, cyclics	na	<0.0005	na	na	~67	~33	C6 paraffins ~3 C7 paraffins ~95 C8 paraffins ~1
	Hydrocarbons, C7, n-alkanes, isoalkanes, cyclics (European)	95 to 99 (203 to 210)	<0.0005	<0.0003	<0.1	~70	~30	na
	Hydrocarbons, C7, n-alkanes, isoalkanes, cyclics (Asia Pacific)	94 to 98 (203 to 210)	<0.1	<0.01	<1.0	~70	~30	na
	Hydrocarbons, C7-C9, n-alkanes, isoalkanes, cyclics (European)	100 to 120 (212 to 248)	~0.0002	0	0	na	na	C7 n-, iso- paraffins ~27 C7 cycloparaffin ~28 C8 paraffins ~45
	Hydrocarbons, C7-C9, n-alkanes, isoalkanes, cyclics (European)	98 to 140 (208 to 284)	~0.04	0	~1	na	na	C6 n-, iso- paraffins ~2 C6 cycloparaffin ~2 C7 n-, iso- paraffins ~17 C7 cycloparaffin ~14 C8 paraffins ~38 Unk paraffins ~37
	Hydrocarbons, C7-	na	na	na	na	~52	~43	C7 paraffins <1.0

	C9, n-alkanes, isoalkanes, cyclics (U.S.)							C8-C9 n-paraffins ~14 C8-C9 isoparaffins ~38 C8-C9 cycloparaffins ~43 Unk paraffins ~4
	Hydrocarbons, C7-C9, n-alkanes, isoalkanes, cyclics (U.S.)	129 to 144 (265 to 291)	~0.5	$<2x10^{-7}$	na	~43	~57	C7-C9 n-, iso, paraffins ~43 C7-C9 cycloparaffins ~57
	Hydrocarbons, C7-C9, n-alkanes, isoalkanes, cyclics	na	~0.1	na	na	~63	~37	C7 paraffins ~32 C8 paraffins ~57 C9 paraffins ~11
	Hydrocarbons, C7-C9, n-alkanes, isoalkanes, cyclics (European)	106 to 136 (223 to 277)	<0.0005	<0.0001	<0.1	~65	~35	na
64742-89-8	Hydrocarbons, C7-C8, cyclics	na	na	na	na	~1-5	~95-99	C7 n-, iso- paraffins ~1-5 C7-C8 cycloparaffins ~95-99
	Hydrocarbons, C7-C9, n-alkanes, isoalkanes, cyclics	na	na	na	na	~47	~51	C6 paraffins ~2 C7 paraffins ~74 C8 paraffins ~22 Unk paraffins ~2
	Hydrocarbons, C7-C9, n-alkanes, isoalkanes, cyclics	na	na	na	na	~46	~48	C7 paraffins ~6 C8 paraffins ~49 C9 paraffins ~39 Unk paraffins ~6
64742-48-9	Hydrocarbons, C8-C10, cyclics (European)	na	na	na	na	~1	~99	C8 cycloparaffins ~2% C9 cycloparaffins ~85% C10 cycloparaffins ~11% C11 cycloparaffins ~1%
92045-53-9	Hydrocarbons, C7, n-alkanes, isoalkanes, cyclics	na	na	na	na	~55	~45	C7 n-paraffin ~25 C7 isoparaffins ~30 C7 cycloparaffin ~45
	Hydrocarbons, C7, n-alkanes, isoalkanes, cyclics (European)	94 to 99 (201 to 210)	~0.001	na	na	~78	~22	C6 cycloparaffin ~1 C7 n-paraffin ~30 C7 isoparaffins ~48 C7 cycloparaffin ~21

90622-56-3	Hydrocarbons, C7-C9, isoalkanes	na	na	na	na	na	na	C7 isoparaffins ~3% C8 isoparaffins ~97%
	Hydrocarbons, C7-C9, isoalkanes	na	na	na	na	na	na	C8 isoparaffins ~68% C9 isoparaffins ~22% C10 isoparaffins ~10%
	Hydrocarbons, C7-C9, isoalkanes (European)	95 to 108 (203 to 226)	~0.002	na	na	~99	~1	C7 isoparaffins ~3% C8 isoparaffins ~97%
	Hydrocarbons, C7-C9, isoalkanes (European)	113 to 143 (235 to 289)	~0.005	na	na	100	0	C8 isoparaffins ~72% C9-C10 isoparaffins ~28%

* a few members may contain up to approximately 3%
** a few members may contain up to approximately 5%
na = not available